

# ON THE PARENT POPULATION OF RADIO GALAXIES AND THE FR I–II DICHOTOMY

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The most promising explanation for the nuclear activity of galaxies is the presence of gas accretion around a massive black hole, and it seems clear now that all galaxies have a massive black hole in their center (Richstone et al. 1998; van der Marel 1999). This suggests that all elliptical galaxies have the basic ingredient for becoming active.

Here we test the possibility that all elliptical galaxies can host radio sources of any power and radio class. In particular, we test whether it is possible to link the optical luminosity function (LF) of non-radio and radio galaxies. To do that, we note that ellipticals of different luminosity might well have different probabilities of forming strong radio sources. Indeed in complete samples of radio sources (Ledlow & Owen 1996; Govoni et al. 2000) a roughly constant number of radio galaxies (RG) is observed between  $-25 < M_R < -21$  mag, indicating the probability of observing radio emission increases strongly with the optical luminosity,  $L$ . To constrain this probability function, we start from the following general assumptions based on empirical result for RG:

(1) The optical LF of non-radio ellipticals is a Schechter function:  $\Phi(L) = \frac{\Phi^*}{L^*} (\frac{L}{L^*})^\alpha e^{-(\frac{L}{L^*})}$ . We set  $L^* = 2.3 \times 10^{11} L_\odot$  (or  $M^* = -22.8$  in the Cousins R band;  $H_0 = 50$  km/s/Mpc;  $q_0 = 0$ ) and  $\alpha = +0.2$ , as found for elliptical galaxies in the Stromlo-APM experiment (Loveday et al. 1992).

(2) All elliptical galaxies of all optical luminosities have the potential of being radio sources, with a probability  $S(L) = S^* (\frac{L}{L^*})^h$ . Where  $S^*$  sets the overall normalization of the function, and  $S(L)$  is dimensionless.

(3) Regardless of  $L$ , once activated, all ellipticals produce radio sources with the same power-law distribution  $N(P) \propto P^{-2}$  (in units of  $P^{-1}$ ; Tofolatti et al. 1987; Urry & Padovani 1995)

(4) In the radio-optical luminosity plane FR I and FR II are separated by a transition line roughly proportional to  $L^2$ , with normalization depending on the frequency under consideration.

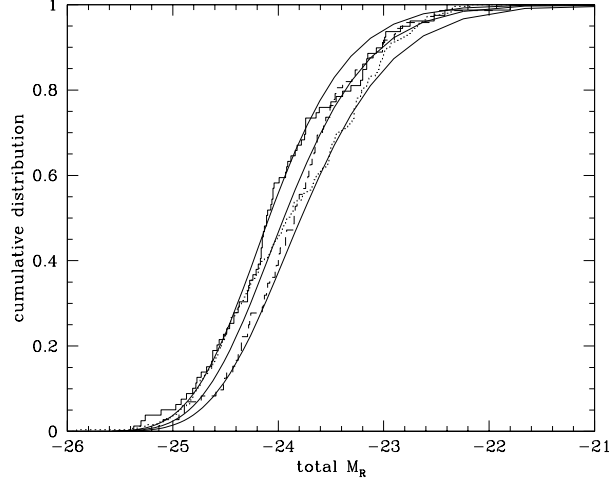
From hypothesis 1 and 2, the normalized cumulative distribution of RG in luminosity  $L$  is given by the incomplete gamma function  $\gamma(1 + \alpha + h, L/L^*)$ . Both constants  $\Phi^*$  and  $S^*$  cancel out, leaving  $h$  as the only free parameter. The best fit to the observations is obtained for  $h = 2 \pm 0.4$  (Fig 1).

Having fixed  $h = 2$ , we then use assumptions 3 and 4 to populate the radio-optical luminosity plan and see whether the introduction of this probability function can explain some known property of RG. In Figures 2 and 3, it is shown that it is indeed possible to reproduce the observed distribution of RG in this plane starting from the LF of non-radio ellipticals. Moreover, our result is consistent with a picture in which FR I and FR II radio sources are hosted by galaxies extracted from the same parent population. No intrinsic differences are necessary to explain the well known difference of  $\sim 0.5$  mag. in optical luminosity between the two classes of radio galaxies (Fig. 4). This is due to the transition region being a increasing function of the optical luminosity (Bicknell 1995).

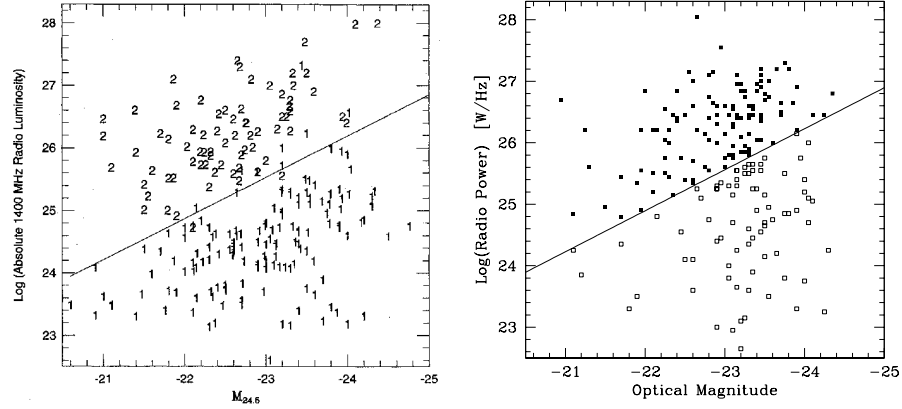
The physical interpretation for this continuity of elliptical galaxy properties across all radio powers is that all ellipticals have a central black hole and therefore have the potential to generate radio sources. Once the radio source is created, its power should depend mainly on accretion rate, which should depend on the availability of gas and stage of development of the accretion activity. It is not too surprising, therefore, that the radio power is largely independent from  $L$ .

## References

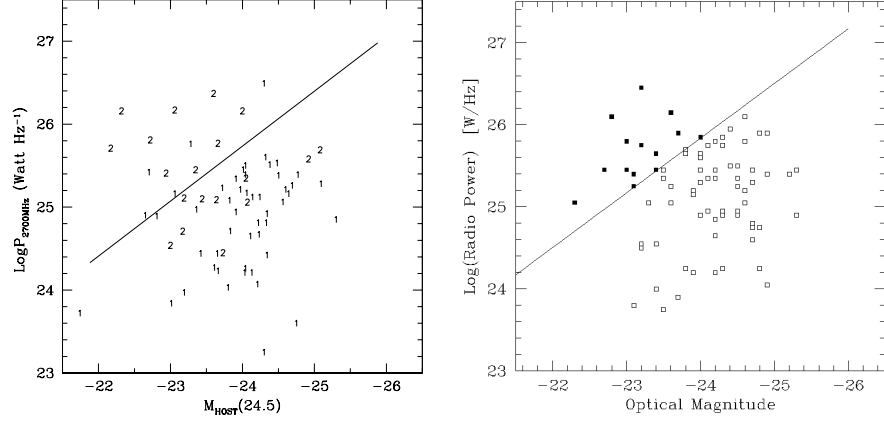
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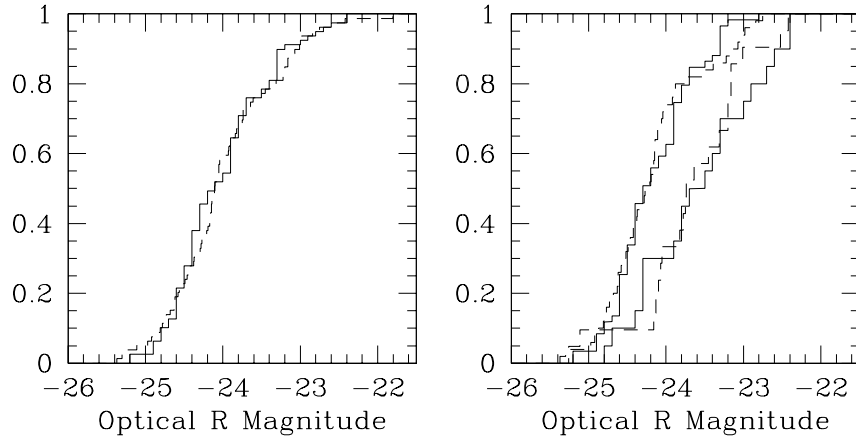
*Figure 1.* Cumulative distribution of optical magnitudes for RG from three different samples and  $H_0 = 50$  km/s/Mpc. **solid line:** Govoni et al. (2000); **dotted line:** Ledlow & Owen (1996); **dashed line:** Smith & Heckman (1989). Superposed to the observed data, are the expected cumulative distribution for RG given by the incomplete gamma function  $\gamma(1 + \alpha + h, L/L^*)$ , for  $h = 2.4, 2.0$ , and  $1.6$ , from left to right, respectively.



*Figure 2.* Radio power versus optical magnitude for RG from multiple radio surveys. **Left:** Observed distribution of FR I (symbol 1) and FR II (symbol 2) from the heterogeneous sample of Ledlow & Owen (1996). The solid line separating FR I from FR II was originally drawn by Ledlow & Owen. **Right:** Representative Monte Carlo simulation for a complete flux-limited sample matching the parameters of the Ledlow & Owen survey. Solid squares represent FR II, open squares FR I, defined entirely by their position with respect to the solid line (same as in left panel). Both source distribution and FR I - II relative population are well reproduced. For consistency with Ledlow & Owen (1996), this figure was computed with  $H_0 = 75$  km/s/Mpc.



*Figure 3.* Radio power versus optical magnitude for RG from a well-defined volume-limited survey. **Left:** Observed data from Govoni et al. (2000). **Right:** Monte Carlo simulation matched to the Govoni et al. selection criteria. The agreement is excellent in both the distribution of sources in the radio-optical luminosity plane and the relative populations of FR I (open squares) and FR II (solid squares). For consistency, this figure is computed with  $H_0 = 50$  km/s/Mpc.



*Figure 4.* Cumulative distributions of R-band absolute magnitudes for RG data and simulations in Fig. 3. Solid line: simulated data; dashed line: observed data. **Left:** Cumulative distribution for the full data set of Govoni et al. (2000). **Right:** Separate cumulative distributions for FR I (left) and FR II (right). Simulated and observed data agree very well, indicating that the observed difference in average optical luminosity between FR I and FR II is essentially a selection effect.